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Perceptual and cognitive characteristics of common playing cards

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Abstract. We examined the perceptual and cognitive characteristics of the playing cards commonly used in the Western world. Specifically, we measured their visibility, memorability, likability, and verbal and visual accessibility. Based on visibility and memorability, four groups of cards were distinguished: the Ace of Spades, other Aces, number cards, and face cards. Within each of these groups, there were few differences due to value or suit. Based on likability and accessibility, three additional groups were distinguished: the Ace of Hearts, Queen of Hearts, and King of Hearts. Several interesting relations were found between how people remember, like, and access cards; some of these were similar to effects found in studies of visual perception, while others seemed entirely new. Our results demonstrate that rigorous examination of real-world stimuli can shed light on the perception of ordinary objects, as well as help us understand why magic works in the mind.

Keywords: magic, playing cards, visual perception, object perception, memory

1 Introduction

Imagine a magician presenting a series of playing cards. A spectator freely selects one of these. Without seeing the chosen card, the magician reveals its name, to the audience's amazement and delight. Spectators call this magic. Magicians call it *forcing*—although the choice felt completely free, the magician heavily influenced the spectator's decision. We want to know why forcing, and other principles of card magic, work.

Magic tricks exploit how people think and perceive. The science of magic examines why such tricks work—what makes them magical—in an effort to better understand the human mind. At least three areas of magic are relevant: illusions, misdirection, and forcing (Kuhn et al 2008). *Illusions* occur when perception diverges from reality. For example, a spectator may see a ball vanish in midair, when it really did not leave the magician's hand (Kuhn and Land 2006; Triplett 1900). *Misdirection* occurs when the magician directs the spectator's attention elsewhere. For example, the magician may direct attention to the left hand to conceal an object in the right. Studying illusions and misdirection has helped illuminate perception, attention, and social cues (Kuhn et al 2009). Studying forcing and related effects may have a similar impact.

To our knowledge, however, no studies to date have systematically examined forcing, or most other card tricks. By doing so we can examine such things as which factors—knowingly or unknowingly—influence our decisions, and how these relate to the feeling of an uninfluenced, conscious choice. For example, will people more likely choose visually distinct stimuli over less distinct ones? Or choose more likable stimuli over less likable ones? More generally, the study of playing cards can also help explore issues such as the relation between the visibility and memorability of stimuli, or between likability and accessibility in long-term memory. In other words, studying card magic can help teach us about the human mind.

The goal of this study, then, is to measure the perceptual and cognitive characteristics of playing cards by adapting techniques used in cognitive and vision science. Measuring the perceptual characteristics of real-world stimuli has proven useful in areas such as information visualisation (eg, Cleveland et al 1982; Rensink and Baldridge 2010). We believe a similar approach will prove useful for playing cards.

A typical Anglo-American deck consists of 52 cards, divided into four suits: Spades (S), Hearts (H), Clubs (C), and Diamonds (D). Each suit contains 13 values: an Ace (A), 9 number cards (2 to 10) and 3 face cards (Jack [J], Queen [Q], and King [K]). On the basis of visual similarity, three groups can be distinguished: Aces, number cards, and face cards.

Although magicians rarely study cards experimentally, they have observed patterns based on performing tricks thousands of times in real-world conditions. From these have arisen two additional distinctions: the Ace of Spades, which generally has a larger and unique pip (spot), and the Queen of Hearts, which many consider a popular card (eg Banachek 2000; Brown 2000).

In this paper we investigated the perceptual and cognitive characteristics of these cards. In particular, we measured five factors that may affect the performance of a card in a magic trick:

- *visibility*: how well the card is identified in a brief display;
- *memorability*: how well it is remembered after being briefly presented;
- *likability*: how much it is preferred;
- *verbal accessibility*: how likely it is chosen when asked to name an arbitrary card;
- *visual accessibility*: how likely it is chosen when asked to visualise a card.

These factors constitute a first approximation of how a playing card may be characterised psychologically. For example, do people treat (ie detect, remember, like, or access) the Ace of Spades differently from other Aces? Aces differently from number cards? Number cards differently from face cards? The Queen of Hearts differently from other Queens? Do value and suit interact with each other within these groups? Finally, do any of the five factors relate to each other? This paper provides a systematic approach to answering these questions. The results can serve as a useful guide for future studies of card magic, and as a method of investigating more general issues of perception and cognition.

2 Studies 1 – 3. General methods

Studies 1, 2, and 3 measured visibility, memorability, and likability. In each experiment, a computer showed pictures of playing cards as part of a task. Each task took 10 to 15 min, and participants completed the tasks individually.

All three tasks shared a common structure as two-alternative forced-choice tasks. Participants first practised the task until they reported feeling comfortable with it. They then completed the actual task, following instructions to emphasise accuracy over speed. Half-way through each task, they took a short break to lessen fatigue. After finishing all three tasks, participants completed a questionnaire for demographic information, then received a debriefing. The order of the three tasks was balanced across participants. All experiments conformed to the university's ethical guidelines.

2.1 *Participants*

Ninety-six students at the University of British Columbia volunteered to complete the experiment for a choice of course credit or money. All had normal or corrected-to-normal vision.

The sample consisted of sixty-two females and thirty-four males, with a median age of 21 years ($M = 22.5$ years, $SD = 3.6$ years). The typical participant spoke English primarily ($n = 64$); first learned English ($n = 24$), Mandarin ($n = 20$), or some unspecified Chinese dialect ($n = 18$); played card games ($n = 62$) such as Big Two ($n = 21$) about 24 min per day (SD = 34.2 min), and used the computer for 6.4 h per day (SD = 3.6 h).

One participant gave the same answer for every trial of the Memorability Task. We replaced these results with those of a new participant. The Likability Task used only half of our participants. This group differed only in age ($M = 21.5$ years, SD = 2.7 years) from the other half ($M = 23.4$ years, SD = 4.3 years).

2.2 *Apparatus and stimuli*

We used a poker-sized deck of Bicycle Playing Cards (United States Playing Card Company, Erlanger, KY, USA), with the cards scanned at 72 dots per inch. To make the scans of the cards appear uniform, we filled the background of each with a solid off-white colour (RGB: 244, 241, 242), centred the card content (ie, the pattern of pips), and rounded the corners. Each card therefore varied only in its pattern, and not in its background colour, size, or shape.

For the practice phase of each task, we used Zener cards, which show only one symbol on each, such as a circle or a star. We believed that these cards would offer a familiar set of stimuli for practice without affecting the performance of particular playing cards (see Bruner and Postman 1949).

The cards appeared on an Apple eMac G4/700 (Cupertino, CA, USA) with a screen measuring 33 deg × 25 deg of visual angle. Participants sat approximately 52 cm away from the screen. Each card measured 8 deg × 11 deg. A computer program (Crimsonite 1.5 by Thomas Dang, 2009) displayed the cards on the screen and recorded the results. A script written in AWK (Aho et al 1987) handled the counterbalancing and randomisation. All statistics used *R*, version 2.13.1 (R Core Development Team, 2011).

3 Study 1: Visibility

3.1 *Procedure*

The Visibility Task measured the relative visibility of the various playing cards. The computer showed a stream of 26 cards while participants searched for a target card—the independent variable—among them. (This was based on a similar design involving other kinds of visual stimuli; see Potter 1976.) For example, participants would try to detect the Ace of Spades in a stream of cards, with accuracy as the dependent variable. (Henceforth, we will abbreviate card names by their value and suit [eg AS].)

At the beginning of each trial, participants saw a target card for 1 s, followed by a rapid-serial visual presentation (RSVP) stream of cards (figure 1). Each card in this stream was displayed for 116 ms with a 0 ms interstimulus interval. Each card

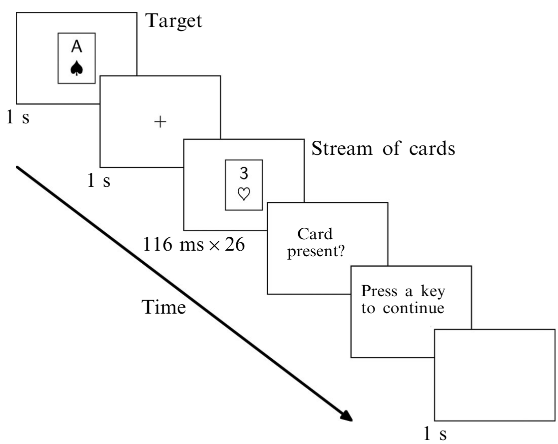


Figure 1. Visibility Task design.

appeared near the centre of the screen, with a random jitter of up to two pixels in any direction. This jitter made the stream look like individual cards being placed one atop the other, rather than a single card simply changing its content. After this, participants indicated whether they saw the target in the stream; chance performance was 50%. At the end of each trial, they pressed a key to continue to the next trial.

Besides the target card, the stream contained randomly selected distractor (non-target) cards, although never the *pair card* of the same value and colour as the target. For example, if the AS was the target, the distractors never included the other black Ace (ie the AC). This was intended to reduce variability in performance; no participants reported noticing this pattern. Overall, the target appeared in half of the trials.

The target card never appeared in the first two nor last two positions in the stream, to reduce serial position effects (see Potter 1976) and to provide a mask for the target. We counterbalanced whether the target would appear in the first half of the stream (positions 3 to 13) or the second half (14 to 24). Within a given half, the target card appeared in a random position. Subsequent analyses showed that target position did not affect performance: neither within the first half of the stream ($F_{10,2485} = 0.81$, $p = 0.62$); nor within the second half ($F_{10,2485} = 0.51$, $p = 0.89$); nor when comparing the halves ($F_{1,4990} = 0$, $p = 0.97$). Consequently, the experiment had a 52 (target card) $\times$ 2 (target presence) $\times$ 2 (target position) design.

Such a design would require 208 conditions per participant. To make the experiment length manageable, we presented each participant with half of the possible conditions: 104 trials. Each participant experienced every target card twice, with only one level of either target presence or target position group. Thus, some participants saw the AS as present in two trials, some as absent in two trials, and some as present once and absent once. This restriction was intended to prevent participants from guessing the next condition of the card and so improving at the task over time. Indeed, performance did not change across trials ($F_{1,9982} = 0.04$, $p = 0.84$).

3.2 *Analysis*

Detection accuracy was our main dependent variable. We calculated the hit rate (declaring a present target present) and false alarm rate (declaring an absent target present) for each card and for each participant. From these rates we calculated sensitivity and bias (Green and Swets 1966).

Sensitivity (d') measures how well one can discriminate a target from a distractor set: for example, how well one can detect the AS among other cards. Higher values suggest better sensitivity. Bias or criterion (c) measures the bias in declaring a target absent, independent of sensitivity. Higher bias values indicate a higher probability of declaring a card absent, or stated differently, a higher threshold for declaring a card present.

The d' and c values lack meaning when the hit or false alarm rates equal 0 or 1. Since calculating the values for each card and participant over only two trials often produces rates of 0 or 1, we grouped every four participants into *supersubjects* (see, eg, Crowder 1982), then calculated d' and c values for each of these 24 supersubjects.[1]

In Study 1, we transformed the d' values to better fit a normal distribution. The raw values had a negative skew, so we reflected the distribution about the y-axis to create a positive skew. Next we shifted the distribution so that the minimum value was

[1] We first calculated overall d' values for each participant. Then we sorted participants by this d' and collapsed two sets of two participants with complementary data sets. Thus, each supersubject viewed every card in every condition twice, and consisted of four participants with similar overall d's. We then calculated d's for each card and supersubject, based on adjusted rates (see Macmillan and Kaplan 1985). This produced 24 d's for each card, upon which we ran the rest of our analysis. We used an analogous procedure to analyse our c values, starting by sorting participants by overall c. The supersubject d's and cs resembled those calculated on the participants as a whole, for both the Visibility and Memorability Tasks (all rs > 0.98, all overall mean differences < 0.04).

positive, to allow for a log transformation. We then log-transformed the values to minimise the skew. These transformations changed no decisions about the null hypotheses. We thus plot the untransformed values for ease of interpretation.

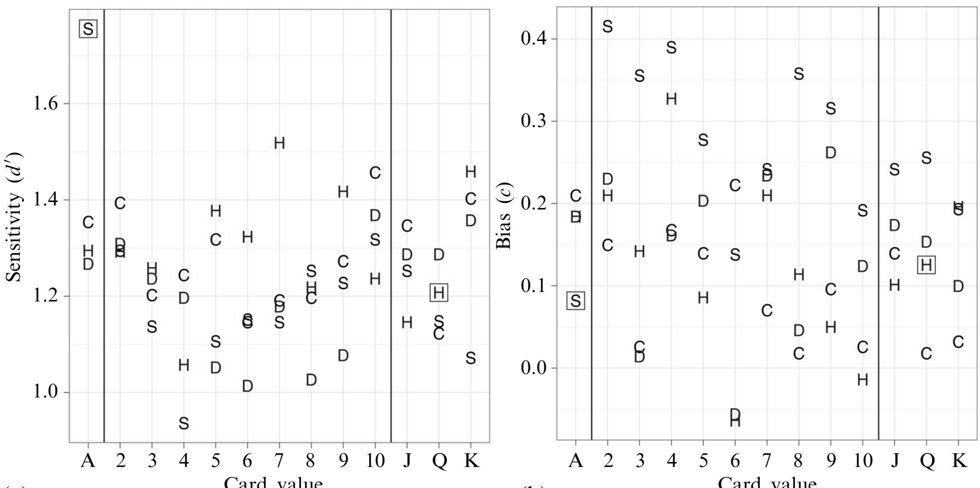
For all of the studies, we examined how performance differed between the five *card groups* distinguished by magicians: the AS, other Aces, number cards, face cards, and QH. For this we used a one-way ANOVA with supersubject in the error term. Next, within each card group, we examined how card value and suit affected performance. For this we used a two-way ANOVA with supersubject in the error term. Both types of tests used the Bonferroni correction, and we report the p and per-test α values (see Perneger 1998).

3.3 *Results and discussion*

3.3.1 *Accuracy.* Overall, participants could detect cards in a stream easily. They answered 80% of the trials correctly, with a hit rate of 75% (range 38% to 100%, SD = 14.15%) and a false alarm rate of 15% (range 0% to 65%, SD = 11.78%). Across all cards, participants showed an average sensitivity of 1.25 (SD = 0.14) and bias of 0.16 (SD = 0.11).

3.3.2 *Questionnaire.* The post-test questionnaire asked whether participants used any strategies during the task. Most of them did ($n = 56$). Many ($n = 34$) reported watching the upper-left pip of the card, and some ($n = 9$) reported only observing the general pattern of the card.

3.3.3 *Sensitivity.* Between card groups, visibility sensitivity varied considerably (figure 2a). Participants detected the AS better than other Aces. The AS has a large and unique pip, making it distinct from every card and presumably aiding detection. Participants also detected other Aces better than number cards. Aces show the simplest pattern—one pip in the middle—making them look distinct from number cards, perhaps again aiding detection. No other differences were found. Interestingly, face cards were no more detectable than number cards, despite their more extensive and varied colours. (See the Visibility d' row of table 1 for means.) Within card groups, sensitivity did not differ by value or suit. (For ANOVA results see table A1 in the online appendix at http://dx.doi.org/10.1068/p7175)



(a) (b)

Figure 2. Visibility sensitivity (a) and bias (b) by card value. Lines and boxes demarcate card groups, as in subsequent graphs.

Table 1. Mean sensitivity (d'), bias (c), and proportions across groups of playing cards.

Study	Measure	AS		Other Aces[a]		Number cards		Face cards[b]	QH		Other Queens[c]
Visibility	d'	1.76	>	1.31	>	1.23	=	1.26	1.21	=	1.19
	c	0.08	=	0.19	=	0.16	=	0.15	0.13	=	0.14
Memorability	d'	1.43	>	0.85	>	0.59	=	0.69	0.74	=	0.68
	c	0.21	=	0.12	=	0.29	>	0.03	0.06	=	0
Likability	P(prefer)[d]	0.77	>	0.62	>	0.46	<	0.54	0.69	>	0.49
Verbal Accessibility	P(choose)	0.246	>	0.039	>	0.007	<	0.022	0.137	>	0.016
Visual Accessibility	P(choose)	0.173	>	0.049	>	0.011	<	0.017	0.1	>	0.013

Note: Equality and inequality symbols between columns show decisions about corresponding means. See respective ANOVA tables for statistics.
[a] Other Aces refers to the average of the AH, AC, and AD, in this table and throughout.
[b] Excludes the QH.
[c] Other Queens refers to the average of the QS, QC, and QD. We did not treat this as a separate card group, but used it for comparing the QH.
[d] Mean preference given two choices. For example, when shown the AS and another card, 77% will prefer the former.

3.3.4 *Bias.* Unlike sensitivity, bias did not differ between card groups (figure 2b). (See the Visibility c row of table 1 for means.) Within card groups, bias depended only on the suit of number cards (figure 3).[(2)] An interesting finding was that participants seemed more likely to declare Spades absent compared to other suits. This did not seem to result from any outliers: the biases of almost all Spade number cards exceeded those of other suits (figure 2b). It is unclear why this would occur. (See table A2 for ANOVA results.)

Two outliers were also found: the red Sixes (6H and 6D). These two seemed to have the lowest biases of all cards (figure 2b). In other words, people seemed most likely to declare red Sixes present when they were absent, compared to any other cards. Some magic tricks exploit the similarity of appearance of Hearts and Diamonds, and between Sixes and Nines. Beyond this, it is unclear why people would misreport seeing red Sixes.

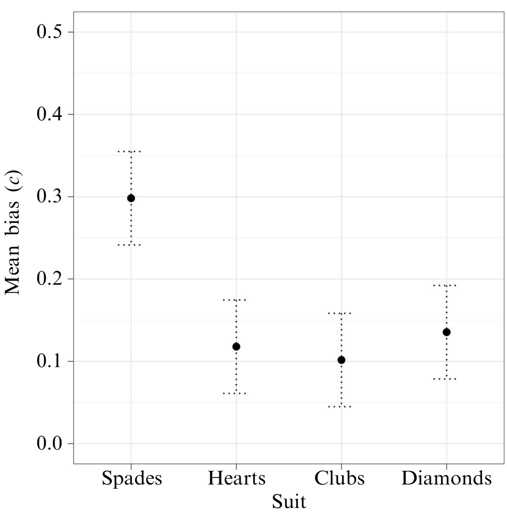


Figure 3. Mean visibility bias by suit of number card.

[(2)] Error bars in all plots show 95% confidence intervals, by convention and for comparing different plots. Note that these 95% intervals suggest a per-test α of 0.05, which we did not use for all hypotheses. See the corresponding ANOVA tables throughout for per-test α values.

4 Study 2: Memorability

The Memorability Task measured how well participants could remember a card that was briefly displayed in an RSVP stream. Its design was in many ways the converse of the Visibility Task: *first* participants saw a stream of cards, *then* a target card appeared.

At the beginning of each trial, participants saw an RSVP stream of seven cards, each for 250 ms with a 0 ms interstimulus interval (figure 4). Each card had a slight jitter in position, as in the Visibility Task. Participants then saw the target card for 1 s, after which they indicated whether they saw it in the stream. Like the Visibility Task, the Memorability Task had 104 trials, using each card as the target twice, and the target was present in half of the trials. Again, accuracy was the dependent variable, with chance performance at 50%.

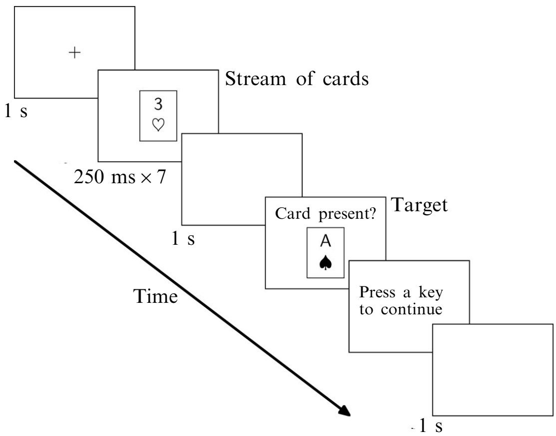


Figure 4. Memorability Task design.

In the stream of seven cards, the target never appeared in the first position nor last two positions.(3) The target, then, had four possible positions (viz 2 through 5), and appeared equally in the first half (positions 2 and 3) and second half (4 and 5). Within a given half, the target card appeared in a random position. Target position did not affect performance: neither within the first half of the stream ($F_{1,2494} = 0.04$, $p = 0.84$); nor within the second half ($F_{1,2494} = 0.95$, $p = 0.33$); nor when comparing the halves, $F_{1,4990} = 1.38$, $p = 0.24$). Consequently, the experiment had a 52 (target card) × 2 (target presence) × 2 (target position) design.

The rest of the stream included random cards, excluding the target's pair card. The six distractors included at least one card from each suit (S, H, C, D) and value group (A – 3, 4 – 6, 7 – 10, J – K). We believed that including a stratified sample of distractors would reduce the participants' likelihood of inferring (non-existent) patterns and so extraneously affecting performance. Indeed, no participants reported seeing patterns in the series of cards, and performance remained constant across trials ($F_{1,9982} = 1.02$, $p = 0.31$).

(3) Pilot studies revealed serial position effects in these positions; avoiding them decreased extraneous variability in performance. Follow-up pilot studies indicated that knowledge of the excluded positions did not substantially improve performance. Only 5 of the 96 participants reported having observed this pattern when asked in the questionnaire if they 'noticed anything'. These five participants seemed to perform better than average, but their performance did not change throughout the trials, so this did not present a confound.

4.1 *Results and discussion*

4.1.1 *Accuracy.* Overall, participants had more trouble remembering cards in a stream than they did detecting them (Study 1). They answered 66% of the trials correctly, with a hit rate of 58% (range 0% to 96%, SD = 16.72%) and a false alarm rate of 27% (range 4% to 69%, SD = 13.47). Across all cards, participants showed an average sensitivity of 0.65 (SD = 0.19) and bias of 0.22 (SD = 0.16).

4.1.2 *Questionnaire.* Most participants ($n = 57$) reported using strategies during the task. Almost half of these ($n = 26$) reported watching the upper-left pip of the card, and many others ($n = 20$) focused on the value rather than the suit.

4.1.3 *Sensitivity.* Between card groups, memorability sensitivity varied considerably (figure 5a). Participants remembered the AS better than other Aces, and other Aces better than number cards. Presumably the distinctiveness of the AS pip, and the distinctiveness of the simplicity of the Aces made them more memorable. No other differences were found. (See the Memorability d' row of table 1 for means.)

Within card groups, sensitivity did not differ, by value or suit. All of these patterns resembled the results of the Visibility Task. (See table A3 for ANOVA results.)

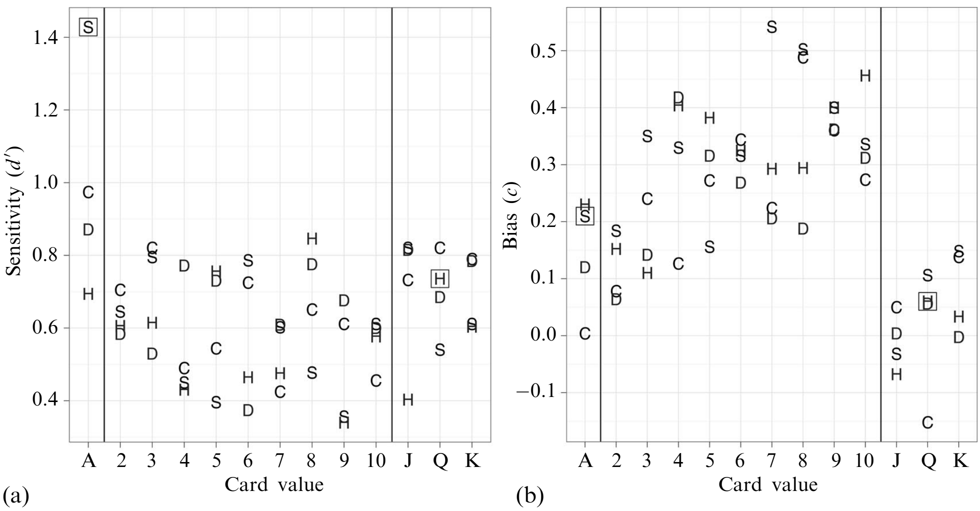


Figure 5. Memorability sensitivity (a) and bias (b) by card value.

4.1.4 *Bias.* Between card groups, bias was higher for number cards than face cards (figure 5b). In other words, participants would more likely declare number cards absent than they would face cards. No other differences were found. (See the Memorability c row of table 1 for means.)

Within card groups, bias depended only on the value of number cards (figure 6). In particular, as the value of the number card increased to four, participants seemed more likely to declare it absent. This was unlikely to be entirely due to visual factors, since visibility did not show a similar pattern. The steady increase of bias from two to four pips may relate to subitising—the ability to rapidly enter up to four items into short-term memory (eg Trick and Pylyshyn 1994). For higher numbers of pips, participants may have felt less confident, as they may have needed more time to count or would have required use of a cruder number sense (eg Lemer et al 2003). As such, participants would more likely declare them absent. (See table A4 for ANOVA results.)

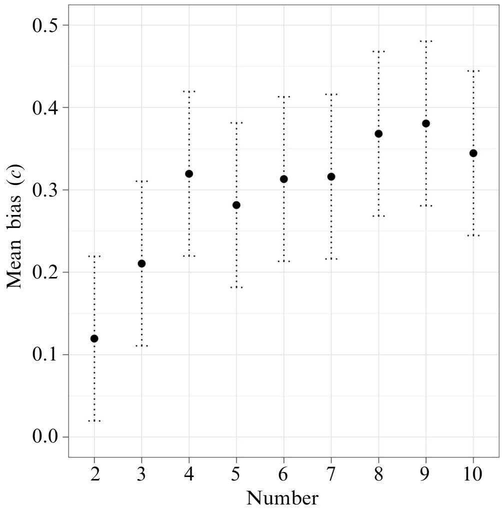


Figure 6. Mean memorability bias by number card value.

5 Study 3: Likability

The Likability Task measured the emotional valence of each card: how much participants liked it. Each trial presented a pair of cards side by side and asked participants to choose the one they liked more. The cards remained visible until the participants responded by pressing the key corresponding to the left or right card. The next trial started 300 ms later.

Each participant saw 156 trials, consisting of two intermixed sets. The first comprised all pairwise comparisons of every different suit for each value. For example, participants saw suit comparisons of Aces (AS – AH, AS – AC, etc), then of Twos (2S – 2H, 2S – 2C, etc), and so on. Given 6 suit combinations for each of the 13 values, this required 78 trials.

The second set comprised all value comparisons within a suit. Each participant saw only one suit, and the selection of suit was counterbalanced across participants. For example, the first participant saw all value comparisons of Spades (AS – 2S, AS – 3S, etc), the next saw all value comparisons of Hearts (AH – 2H, AH – 3H, etc), and so on. This also required 78 trials.

Overall, each card appeared an equal number of times, and equally on the left and right side of the screen. To do this, the cards appeared in one permutation (eg AS – 2S) for half of the participants and the reverse (eg 2S – AS) for the other half. Participants showed a slight preference for cards on the right side of the screen: 52% preferred cards on the right side ($t_{7487} = 3.56$, $p < 0.001$). This preference increased only slightly over trials ($F_{1,7486} = 5.23$, $p = 0.02$, $\beta_1 = 0.001$).

5.1 *Analysis*

The dependent variable was preference: the probability of a given card being preferred. This ranged from 0 to 1, with 0.5 meaning that the card was preferred half of the time it was displayed. Our analyses used Bonferroni-corrected Pearson's χ^2 tests on the raw frequency data.

5.2 *Results and discussion*

5.2.1 *Questionnaire.* Most participants ($n = 38$) reported using strategies during the task.(4) Many of them ($n = 28$) used a specific rule for preference, based on a preferred card or set of cards. Some reported preferring higher-valued cards ($n = 10$);

(4) Recall that the Likability Task used only 48 participants.

others preferred lower cards ($n = 3$) or those with a simpler pattern ($n = 3$). Two reported preferring cards based on their rank in the game Big Two.(5)

5.2.2 *Preference.* Between card groups, preference differed considerably (figure 7). Participants preferred the AS over other Aces, perhaps due to its popularity or high rank in card games. They also preferred other Aces over number cards, perhaps due to their simple pattern and high rank. As opposed to some of the patterns found for visibility and memorability, face cards and number cards could now be distinguished, perhaps partly due to their higher rank or colourful pictures. They also preferred the QH over other Queens, but perhaps only due to its highly liked suit. Indeed, the QH did not seem like an extreme outlier (figure C1). (See the Likability row of table 1 for means.)

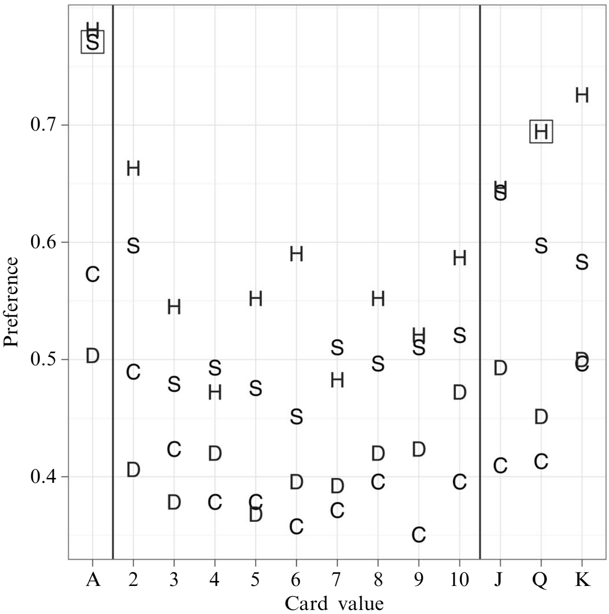


Figure 7. Preference by card value.

Within card groups, preference depended on both value and suit. For value, participants seemed to like Twos and Tens—the highest and the lowest values—the most, and the rest of the values equally (figure C2). The questionnaire responses suggest two possible explanations. First, participants often reported liking high or low cards versus middle-valued cards. Second, many participants played Big Two and some reported preferring high-ranking cards in the game: namely, Twos, and higher number cards. Indeed, players of Big Two seemed to prefer Twos more than non-players did (figure 8).

For suit, participants seemed to show a general pattern of preferring Spades and Hearts over Clubs and Diamonds across all card groups (figures C3, C4, and C5). This may have occurred due to their rank in card games (eg in the card game Hearts). Or, perhaps it occurred because people prefer curved shapes (Bar and Neta 2006): Spades and Hearts have more curved shapes compared to the less smooth shape of Clubs and sharp shape of Diamonds. People also prefer simple shapes (Day 1967), and Clubs have a particularly complex shape compared to the other suits, perhaps making it the least liked suit.

(5) In Big Two, card values rank from highest to lowest as Twos, Aces, Kings, Queens, Jacks, and Tens, down to Threes. Suits rank as Spades, Hearts, Clubs, then Diamonds.

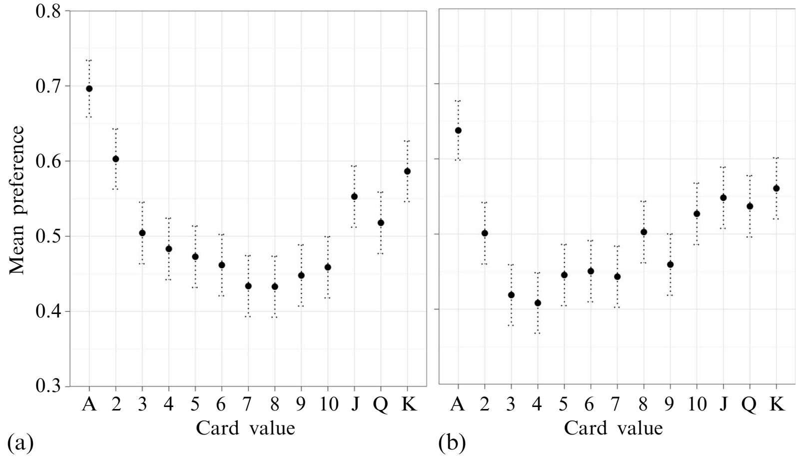


Figure 8. Mean preference for card values in players (a; $n = 11$) and non-players (b; $n = 37$) of Big Two. Gender proportions were similar for both groups.

Finally, preference within face cards depended on the interaction of value and suit (figure C1). In other words, participants seemed to like particular face cards more than others. Face cards vary considerably in their patterns and colours, and also in the expression on the faces. Subtle changes in expression may have affected preference (Lundqvist et al 1999), along with the larger changes in pattern.

There were two unexpected outliers: the AH and KH (figure 7). Perhaps the interaction of the highly liked value and highly liked suit made participants particularly prefer these cards.

We also saw some gender differences. Women seemed to prefer lower-valued cards more, and men higher-valued ones (figure 9). Indeed, in the questionnaire more men (28%) reported liking higher values, and no men reported liking lower values. Women did not show this pattern: the same amount (13%) reported liking lower and higher values. This did not seem to be due to differences in their favourite card game. Regardless of the game, most women preferred lower values, and most men higher values.

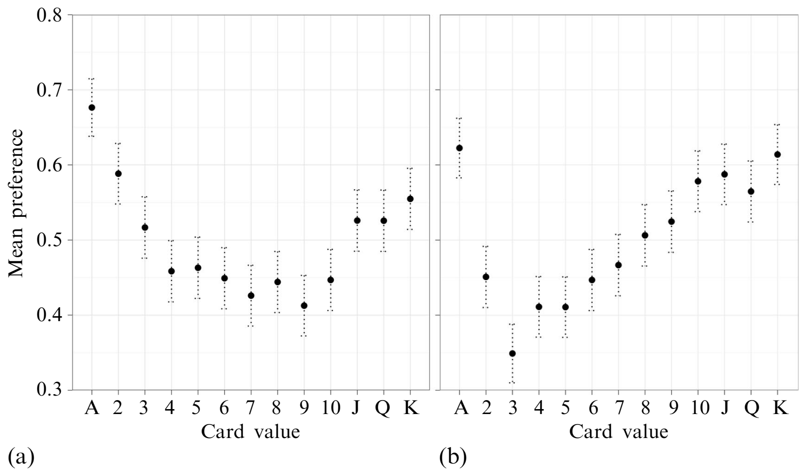


Figure 9. Mean preference for card values in women (a; $n = 31$) and men (b; $n = 17$).

6 Study 4: Verbal Accessibility

As mentioned earlier, magicians will often ask spectators to verbally choose any card. The Verbal Accessibility study therefore measured a factor critical to such tricks: how likely a card will come to mind when the spectator is asked to name an arbitrary card. R A Fisher (1928), for example, observed that people show tendencies to name particular cards when trying to guess a card randomly drawn from a deck. Woolley (1928) reported that people often choose Aces—especially the AS—and odd cards when trying to do this. Banachek (2000) constructed a list of frequently chosen cards, based on "trial and error" as part of a magic trick asking spectators to name a card (personal communication, 2009). His and other magicians' lists prioritise Aces, face cards, and certain low number cards (table 2). We measured the accessibility of playing cards in a similar, but more systematic, way.

Table 2. Frequently chosen cards.

Source	Cards
Banachek 2000[a]	AS, QH, AH, KH, JS, AD, QS, JD, 3S, 3H, 10H
Verbal Accessibility (Study 4)[b]	AS; QH; AH; KH; JS; AD; JH; KS; QS, JD, QD, 7H
Visual Accessibility (Study 5)[b]	AS; AH; QH; KH; 3D; JS, 5H, 8C; AD; 8S, 10H, JH
Magic context[c]	AS, AH; KH; QH, QD, 2H

Note: Commas separate ties—cards chosen the same number of times. Semicolons do not.
[a] Cards sorted to match verbal accessibility data, since frequencies were not provided.
[b] Top-quartile data.
[c] Cards chosen more than once.

6.1 *Methods*

6.1.1 *Procedure.* We asked participants to name an arbitrary card, using two analogous procedures: in-person and online. We collected the in-person data at a lab and a local science centre. At the lab, we recruited participants arriving for other experiments; at the science centre, we recruited visitors aged over 18 years. For both procedures, we tried to avoid words that might prime specific numbers. For example, claiming that the questionnaire will "ask a few questions" might prime numbers corresponding to 'few', such as two or three (eg Brown 2000; Kubovy 1977). Even claiming that "we are going *to* ask questions" might prime the homonym 'two' (eg Lesch and Pollatsek 1993). We instead tried to maintain a more neutral wording. We asked the following:

> "We're doing a study on playing cards. May I ask you questions about cards? (If yes:) Name a playing card. Was that the first card that came to mind? Have you been asked these questions before? What is your age (not mandatory)?"

The experimenter also recorded the participant's gender, then explained the study.

The online version used a questionnaire split over several pages. The first page stated, "We're doing a study on playing cards. This questionnaire will ask you questions about cards." After clicking 'Next', the website asked to "Name a playing card" and gave an empty field in which to type the name of a card (eg 'Ace of Spades'). We then asked the same questions as the in-person procedure with the addition of gender.

6.1.2 *Participants.* In total, we asked 667 participants to name a card. The in-person group ($n = 147$) had a median age of 22 years ($M = 26.6$ years, SD = 11.2 years), and consisted of 56% women and 44% men. The online group ($n = 520$) consisted primarily of undergraduate psychology students who learned about the questionnaire through e-mail. They had a median age of 22 years ($M = 29.9$ years, SD = 14.2 years) and consisted of 33% women and 66% men.

6.1.3 *Analysis.* For all responses, we first omitted participants who reported having previously completed a similar questionnaire ($n = 36$). We then omitted those who reported choosing a card different from the first one that came to mind ($n = 87$). For the in-person data, we omitted those participants who paused for more than two seconds before answering, or who first said anything other than a playing card ($n = 21$).

We passed the online responses through a parser which matched the inputted text (eg 'Ace of Spades') to a playing card. The parser looked for common misspellings (eg 'Dimond' for 'Diamond') and alternate names (eg 'Clover' for 'Club'). It omitted responses describing non-cards (eg 'Joe'), ambiguous cards (eg 'Queen'), and Jokers. We ended up with 423 (113 in-person, 310 online) valid responses. This subset of participants had a median age of 23 years ($M = 29.4$ years, SD $= 14.8$ years), and consisted of 39% women and 61% men.

People generally chose the same cards in person and online. We found a high Spearman's rank correlation between these data sets ($r_S = 0.61$) and so combined them. The dependent variable, then, was the probability of choosing a particular card. As in the Likability Task, our analyses used Bonferroni-corrected Pearson's χ^2 tests on the raw frequency data.

6.2 *Results and discussion*
Participants showed strong tendencies to verbally select particular cards (figure 10a). Between and within card groups, they showed the same pattern of results as in the Likability Task (cf tables A5 and A6). The AS was by far the most chosen, followed by the QH, and then other high-ranking cards (see the Verbal Accessibility row of table 2). (See the Verbal Accessibility row of table 1 for means, and table A6 for χ^2 results.)

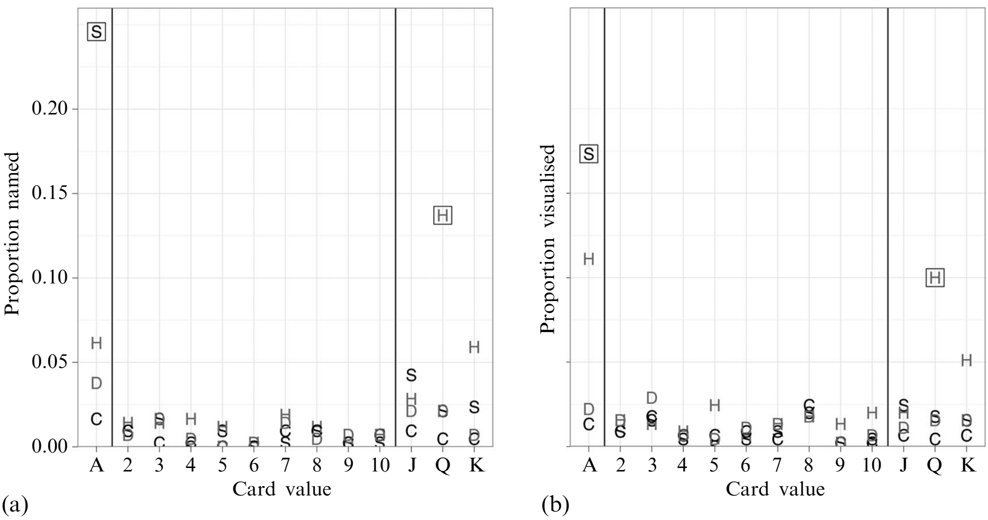


Figure 10. Proportion named (a; $N = 423$) and visualised (b; $N = 450$; Study 5) by card value.

Choice of card depended on value only within number cards (figure 11a). Participants named Threes and Sevens the most, and Sixes the least. Magicians have noticed that people often choose three and seven when asked in magic tricks to choose a number out of five or ten, respectively (Banachek 2000). Likewise, researchers have found that people tend to choose three or seven the most when asked to pick the first digit that comes to mind (Kubovy 1977; Kubovy and Psotka 1976).

Choice also depended on suit. Participants seemed to show a pattern of choosing Spades or Hearts the most (figures C6, C7, and C8), again following the pattern found in the Likability Task.

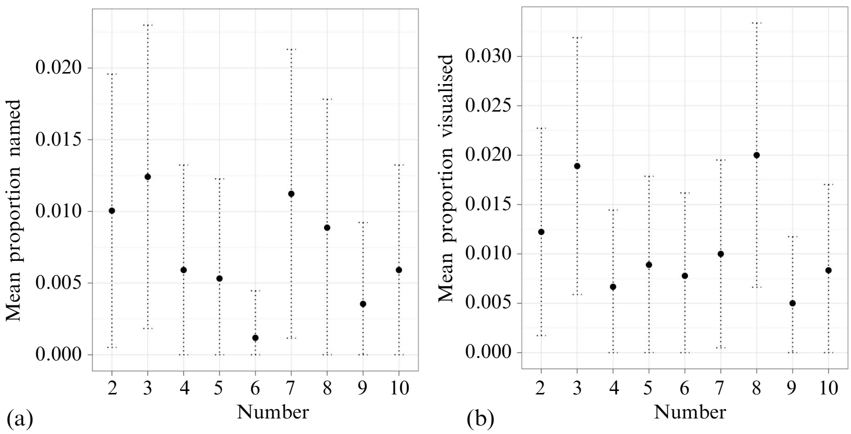


Figure 11. Mean proportion of number cards named (a) and visualised (b; Study 5) by value.

Finally, choice depended on the interaction of value and suit, within face cards (figure C9). Again, as in the Likability Task, the AH and KH were outliers, though less extreme ones (figure 10a).

We also saw some gender differences. One may expect women to choose the QH more frequently (eg Banachek 2000), and men the KH, given the gender of the characters on the cards. Interestingly, we saw the opposite pattern (figure 12a).

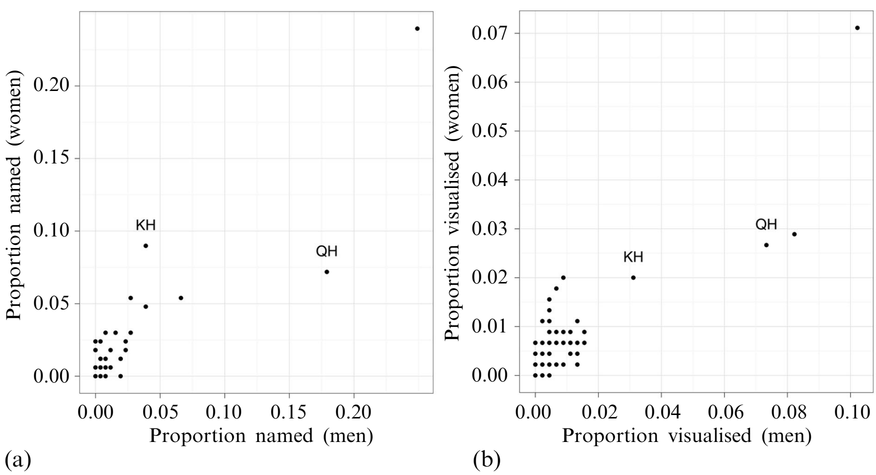


Figure 12. Verbal (a) and visual (b; Study 5) accessibility in women and men.

6.3 *Generalisability*

Our list of frequently chosen cards corresponded fairly well to those obtained by magicians. For example, 8 of Banachek's 11 frequently chosen cards matched our top-quartile data (cf the Banachek and Verbal Accessibility rows of table 2). Nevertheless, our results may have diverged somewhat from those of other magicians because our study lacked a magic context—the card choices did not occur as part of a magic trick. To test our results in a more natural environment, we approached 30 student-aged groups of people over two nights at a bar. We presented a magic trick in which the spectator would name an arbitrary card; we did not mention the research until after the trick. Of the six cards chosen more than once, five corresponded to our top accessibility rankings. (See the Magic context row of table 2.) Our results thus seem to represent choices made in a magic context, at least for people in this region and age group.

7 Study 5: Visual Accessibility

The Visual Accessibility study explored whether people choose cards differently if asked to *visualise* rather than *name* them. Differences are known to exist between verbal and non-verbal encoding of stimuli (eg Paivio 1991). When asked to visualise a playing card, people might visually construct a card rather than simply retrieve a verbal label, and thus might tend to choose different types of cards.

7.1 *Methods*

7.1.1 *Procedure.* We used the same online procedure as in Study 4, except that rather than asking people to "Name a playing card", they were asked to "Visualise a playing card. . . . What is it?".

7.1.2 *Participants.* We began with 700 participants, who consisted primarily of undergraduate psychology students who learned about the questionnaire through e-mail. They had a median age of 21 years ($M = 25.5$ years, SD = 10.5 years), and consisted of 43% women and 57% men.

As in Study 4, we omitted participants who reported participating in a similar experiment ($n = 67$) and those who reported that another card came to mind first ($n = 120$). We passed the data through the same parser and ended up with 450 valid responses. This subset of the participants had a median age of 22 years ($M = 25.9$ years, SD = 11 years), and consisted of 43% women and 57% men.

7.1.3 *Analysis.* The dependent variable was again the probability of choosing a particular card. As in Studies 3 and 4, our analyses used Bonferroni-corrected Pearson's χ^2 tests on the raw frequency data.

7.2 *Results and discussion*

As in the case of verbal accessibility, participants showed strong tendencies to choose particular cards (figure 10b). Between and within card groups, they showed exactly the same pattern as in the Likability and Verbal Accessibility Tasks (cf tables A5, A6, and A7; see figures C10, 11b, C11, C12, and C13). We again saw the outlying AH and KH (figure 10b), and the preference for the QH by men more than women (figure 12b).

Our results do not suggest an overall tendency to choose red suits when visualising (cf figures C7 and C11). Interestingly, participants seemed to choose the AH more often when asked to visualise a card rather than name one (cf figures 10a and 10b, or the Verbal and Visual Accessibility rows of table 2). Perhaps asking to visualise a card makes particular red cards more accessible. Some magicians believe this occurs because visualising brings vivid colours to mind, such as red rather than black. However, this may reflect differences in verbal and non-verbal processing (Clark and Paivio 1991; Paivio 1991). (See the Visual Accessibility row of table 1 for means, and table A7 for χ^2 results. See the Visual Accessibility row of table 2 for frequently chosen cards.)

8 General results

An interesting question is how the seven factors we have investigated here relate to each other. To answer this, we first removed the four outliers (AS, QH, AH, and KH). We then plotted the linear-fitted values and residuals for each pair of factors. Factors whose plots showed strong systematic patterns were classified as having a non-linear relationship. The other factors were used in one-way ANOVAs to determine the presence of a linear relationship.

Several interesting relationships emerged. Memorability bias was negatively correlated with verbal accessibility (figure 13a; $R^2_{\text{NL}} = 0.21$)[6] and somewhat negatively correlated with visual accessibility (figure 13b; $R^2_{\text{NL}} = 0.05$). In other words, participants would tend to

[6] R^2_{NL} refers to a non-linear proportion of variance explained. It is computed by dividing the variance of the LOESS predicted values of Y by the variance of Y.

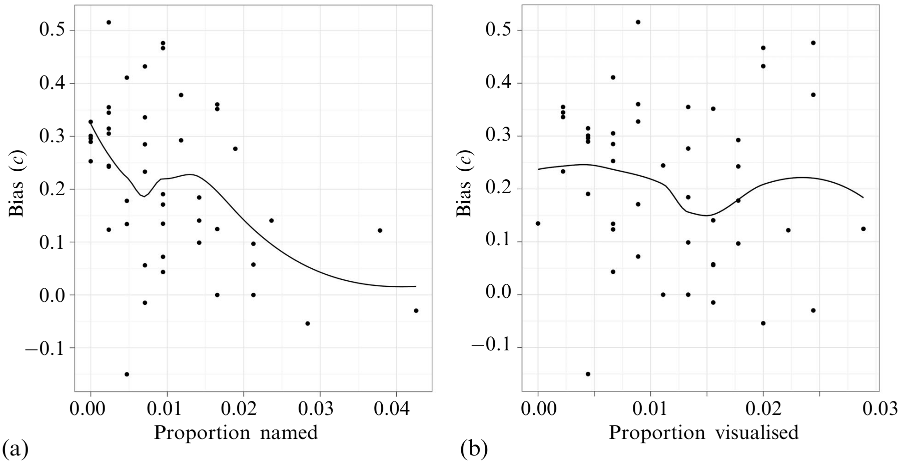


Figure 13. Memorability bias versus verbal (a) and visual (b) accessibility. Line shows LOESS fitted curve, as in subsequent scatterplots.

misreport seeing highly accessible cards. Perhaps, during the Accessibility Tasks, cards with the lowest threshold (ie memorability bias) activated first and participants would then choose them. Alternatively, during the Memorability Task, when participants tried to recall which cards appeared in the stream, highly accessible cards may have come to mind more easily and so were more likely to be declared present (see, eg, Whittlesea 1993).

Verbal accessibility was in turn positively correlated with both likability (figure 14a; $R^2_{\mathrm{NL}} = 0.29$) and visual accessibility (figure 14b; $R^2_{\mathrm{NL}} = 0.34$). As verbal accessibility increased,

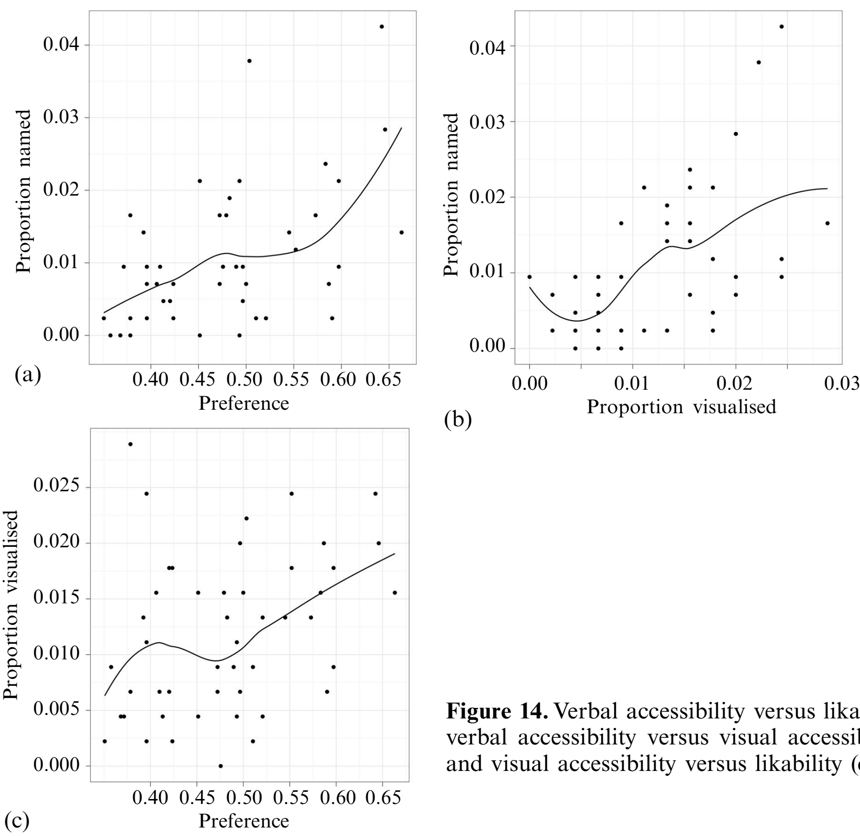


Figure 14. Verbal accessibility versus likability (a), verbal accessibility versus visual accessibility (b), and visual accessibility versus likability (c).

likability and visual accessibility increased. Further, likability and visual accessibility themselves were positively correlated (figure 14c; $R^2_{NL} = 0.16$). All three measures presumably reflect the popularity of particular cards.

Between the AS, other Aces, and number cards, we saw the same pattern of means for visibility sensitivity, memorability sensitivity, likability, and both types of accessibility (table 1). Between all card groups, likability and accessibility also showed the same pattern of means (table 1), and main and interaction effects (cf tables A5, A6, and A7). We did not see any other relationships. See table B1 for data for each card.

9 General discussion

In this paper we examined several perceptual and cognitive characteristics of common playing cards. Specifically, we measured how well people detect, remember, like, and access each of the 52 cards in a typical Anglo-American deck. Our general conclusions: people treat various cards differently, in ways that largely reflect the patterns observed by magicians, with some interesting exceptions.

At a general level, our results show that playing cards can be classified into several different groups, with the granularity of these depending on the task. For lower-level tasks, such as detecting or remembering, there appear to be four basic groups: the AS, other Aces, number cards, and face cards. Within each of these groups, performance does not vary with the value and suit of the card. Even within number cards, performance does not change: participants could detect and remember higher cards like Tens about as well as Twos.

For higher-level tasks, such as liking or accessing, an additional three groups emerge: the AH, QH, and KH. Within the groups, performance can vary considerably by value, suit, and interaction of value and suit.

We also found several exceptions to the general patterns above, which raised a number of interesting questions:

- Study 1: Why are people relatively reluctant to declare number cards present if they are Spades?
- Study 1: Why are people highly likely to misreport seeing red Sixes, even though these cards are not highly accessible (Studies 4 and 5)?
- Studies 3, 4, and 5: Why do people prefer and choose Spades and Hearts over Clubs and Diamonds?
- Studies 3, 4, and 5: Why is the KH an outlier in higher-level tasks?
- Study 4: Why do men choose the QH more than women do, and women choose the KH more than men do?
- Study 5: Why do people choose only the AH more often when asked to visualise rather than name a card?

The answers to these may provide interesting insights into the nature of human perception and cognition.

9.1 *Connections to visual perception*

Several of our results appear to connect to various aspects of visual perception, including the perception of ordinary objects. For example, people can better detect and remember stimuli such as Aces, which are relatively distinct visually. We also found that the memorability bias of number cards increases with the number of pips up to a limit of four, which may reflect the greater confidence placed in subitising rather than counting (eg Lemer et al 2003).

Such connections also extended to higher-level tasks. For example, people preferred the smooth, simple shapes of Spades and Hearts over the pointed, complex shapes of Clubs and Diamonds. In addition, memorability bias related to accessibility, suggesting that more accessible stimuli come to mind easier, and so are more likely to be declared present. It was also found that in the Accessibility Tasks, changes in the wording of a question can bring different cards to mind, possibly reflecting differences in verbal and non-verbal processing found in other tasks and stimuli (eg Paivio 1991).

9.2 *Future directions*

Although this study uncovered several interesting new phenomena, it has several limitations. First, we made no attempt to obtain a representative sample of participants in terms of age, gender, or culture. As such, our results can only roughly approximate the perceptual and cognitive characteristics of cards as experienced by the general population. Indeed, given the dependence of various perceptual and cognitive processes on culture (see Nisbett 2003), an interesting direction for future research is the extent to which the factors discussed here depend on culture.

Second, our broad approach excluded some potentially interesting issues dealing with gender or individual differences. For example, do females and males detect or remember the QH differently? Do people with particular lucky or unlucky numbers treat these corresponding card numbers differently? How do visibility, memorability, and likability relate within each person?

In spite of these limitations, we believe that the results obtained here can serve as the foundation for more rigorous studies of card magic. For example, given the various characteristics of cards as mapped out here, we can design studies to better understand how forcing works, and how it relates to the feeling of a conscious will making decisions. This could allow us to examine why people feel they have such control over a decision even when in reality they have little.

In sum, this study has shown that it is possible to rigorously assess various perceptual and cognitive characteristics of playing cards. This domain has turned out to contain several interesting phenomena, some of which may provide new perspectives on how people perceive and evaluate ordinary objects. The results obtained here may also serve as a foundation to better understand how magic works in the mind.

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